INTERNATIONAL FOOD
POLICY RESEARCH INSTITUTE

sustainable solutions for ending hunger and poverty

Supported by the CGIAR

IFPRI Discussion Paper 00945

January 2010

Toward a Typology of Food Security in Developing Countries

Bingxin Yu

Liangzhi You

Shenggen Fan

Development Strategy and Governance Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI) was established in 1975. IFPRI is one of 15 agricultural research centers that receive principal funding from governments, private foundations, and international and regional organizations, most of which are members of the Consultative Group on International Agricultural Research (CGIAR).

FINANCIAL CONTRIBUTORS AND PARTNERS

IFPRI's research, capacity strengthening, and communications work is made possible by its financial contributors and partners. IFPRI receives its principal funding from governments, private foundations, and international and regional organizations, most of which are members of the Consultative Group on International Agricultural Research (CGIAR). IFPRI gratefully acknowledges the generous unrestricted funding from Australia, Canada, China, Finland, France, Germany, India, Ireland, Italy, Japan, Netherlands, Norway, South Africa, Sweden, Switzerland, United Kingdom, United States, and World Bank.

AUTHORS

Bingxin Yu, International Food Policy Research Institute
Postdoctoral Fellow, Development Strategy and Governance Division
b.yu@cgiar.org

Lingzhi You, International Food Policy Research Institute
Senior Scientist, Environment and Production Technology Division
l.you@cgiar.org

Shenggen Fan, International Food Policy Research Institute
Director General, Director General Office
s.fan@cgiar.org

Notices

[1] Effective January 2007, the Discussion Paper series within each division and the Director General's Office of IFPRI were merged into one IFPRI–wide Discussion Paper series. The new series begins with number 00689, reflecting the prior publication of 688 discussion papers within the dispersed series. The earlier series are available on IFPRI's website at http://www.ifpri.org/category/publication-type/discussion-papers.

[2] IFPRI Discussion Papers contain preliminary material and research results. They have not been subject to formal external reviews managed by IFPRI's Publications Review Committee but have been reviewed by at least one internal and/or external reviewer. They are circulated in order to stimulate discussion and critical comment.

Contents

List of Tables

List of Figures

ACKNOWLEDGEMENT

The authors acknowledge financial support from the United States Agency for International Development.

ABSTRACT

The recent global food and financial crises have reversed the last decade's progress in reducing hunger and poverty. This paper conducts a factor and sequential typology analysis to identify groups of countries categorized according to five measures of food security—consumption, production, imports, distribution, and agricultural potential—by using indicators from 175 countries. The analysis first identifies five distinct food security groups, characterized by food intake, and then further splits these groups based on the various measures of food production, trade security, and agricultural potential. The results suggest that the general category of "developing countries" is extremely heterogeneous and is not particularly useful if the focus is on issues of food security. The results also indicate that different responses are needed by different types of food-insecure countries to address the food and financial crises.

Key Words: food security, typology, agricultural potential, factor analysis

JEL Code: C0, F0, O1

.

1. INTRODUCTION

In 1990, the international community and national governments set an ambitious target of achieving Millennium Development Goals (MDGs) by 2015. While a number of countries are currently on track, achieving these targets remains a challenge for many others. The rapid food price increase between 2005 and 2008 and recent economic recessions have further dampened global efforts to achieve the MDGs. High food prices and the economic slowdown have pushed 255–290 million more people into extreme poverty (FAO 2009). The chronically hungry population is expected to rise from 850 million in 2007 to more than one billion in 2009. The long-run consequences of the crisis, in terms of human development outcomes, may be even more severe than the effects observed in the short run.

At the country level, net food exporters benefit from the high prices with favorable terms of trade, although some countries are missing out by banning exports to protect domestic consumers. However, net food importers are struggling to meet domestic demand (von Braun et al. 2008). High food prices have especially affected many African countries, as most of them are net cereal importers. Even within the net exporting countries, many poor still suffer, because many of them are net buyers of food. This is particularly detrimental to the poorest poor, as they often spend 60–80 percent of their income on food. In net food-importing countries, not only do the poorest suffer even more disproportionately, but increased food-importing bills might also crowd out other imports such as energy and capital-intensive equipment. Thus, it is important to understand the level and cause of—and possible solutions to—food insecurity in those countries.

The World Food Summit defined the multiple dimensions of food security as food accessibility, availability, use, and stability. Using factor and sequential analysis, we develop a classification of 175 countries based on their situation with regard to various aspects of food security. This approach stems from Adelman and Morris (1967), who argued that development is a multifaceted and nonlinear process, and countries at different development stages require different strategies. Using factor analysis, they classified each country's growth according to the country's characteristics, focusing on social and political variables. This paper contributes to the typology of food security by taking a more aggregate viewpoint and by classifying countries according to the various dimensions of food security. We attempt to take into account the comprehensive driving forces behind the evolution of the concept of food security over time. Hence, the analysis considers not only the traditional perception of food production and nutritional intake, but also the potential to augment food supply by considering their natural resource endowments. In addition, the role of the nonagricultural sector in the economy and a country's ability to meet the cost of importing food from the international market are included.

Previous efforts by Diaz-Bonilla et al. (2000) provide a snapshot of the food security situation in the mid-1990s. This study further extends their work and serves four objectives: to assess food security in the consumption dimension, to examine food affordability in the trade dimension, to investigate the sources of food insecurity in the production dimension, and to identify long-term potential to boost food production in the agricultural potential dimension. The resulting classification allows for a broader view of the problem: which countries face similar food security situations and therefore might be able to learn from each other's successes and failures? While standard measures such as per capita income levels and net food imports are useful, we examine a more nuanced picture using a broader array of indicators because the more conventional measures ignore the broad economic and natural resource conditions and the composition of trade. For instance, tourist destinations such as Barbados may have high levels of food imports, but they are not at risk of food insecurity. In general, we find that country-specific measures (the composition of trade and comparative advantages in agricultural production) provide a more accurate indication of food insecurity than do broader regional characteristics.

It is recognized that different research issues can lead to different classifications and hence different typologies. For example, Diaz-Bonilla et al. (2000) analyze the trade aspect of food security typology, while Zhang, Rockmore, and Chamberlin (2007) consider vulnerability reduction from a macro view. This paper differs from other studies in that it links food security with its sources and potential policy instruments: the country's food production and natural conditions. Since increased agricultural production is the most effective and efficient instrument to improve food security for many poor countries over the long haul, the key question is what types of countries can use trade and what types of countries can use domestic production to secure food supply. Different types of countries require appropriately tailored policies to achieve food security, and there is no one-size-fits-all solution. Another contribution of this study is the consideration of both short- and long-term aspects of food security. Agricultural potential captures the possibility of long-term food production and identifies countries lacking the capacity to meet domestic food demand through production within the country's borders. Trade position, in contrast, is somewhat more of a short-term solution to increase food availability though imports from the rest of the world.

The paper is organized as follows. The framework for food security analysis is presented in the next section, including a rationale for the selection of food security indicators considered for the typology analysis. The third section briefly describes the methodology used—factor analysis and sequential typology analysis. In the fourth section, the suggested typology of countries is discussed in greater detail. The evolution of food security since 2000 is discussed in the fifth section. The last section concludes with specific policy recommendations for each type of country.

2. THE FRAMEWORK FOR FOOD SECURITY

Theoretical Framework

There are multiple definitions of food security and the concepts of food security have evolved in the last 30 years to reflect changes in official policy thinking (Clay 2002; Heidhues et al. 2004). The term first originated in the mid-1970s, when the World Food Conference defined food security at the international and national level as a food supply that could ensure the availability and price stability of basic foodstuffs: "food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO 1996a). The definition was later extended by the Food and Agriculture Organization of the United Nations (FAO) to include individual- and household-level access (Clay 2002). The widely accepted World Food Summit definition reinforces the multidimensional nature of food security as including food accessibility, availability, utilization, and stability.

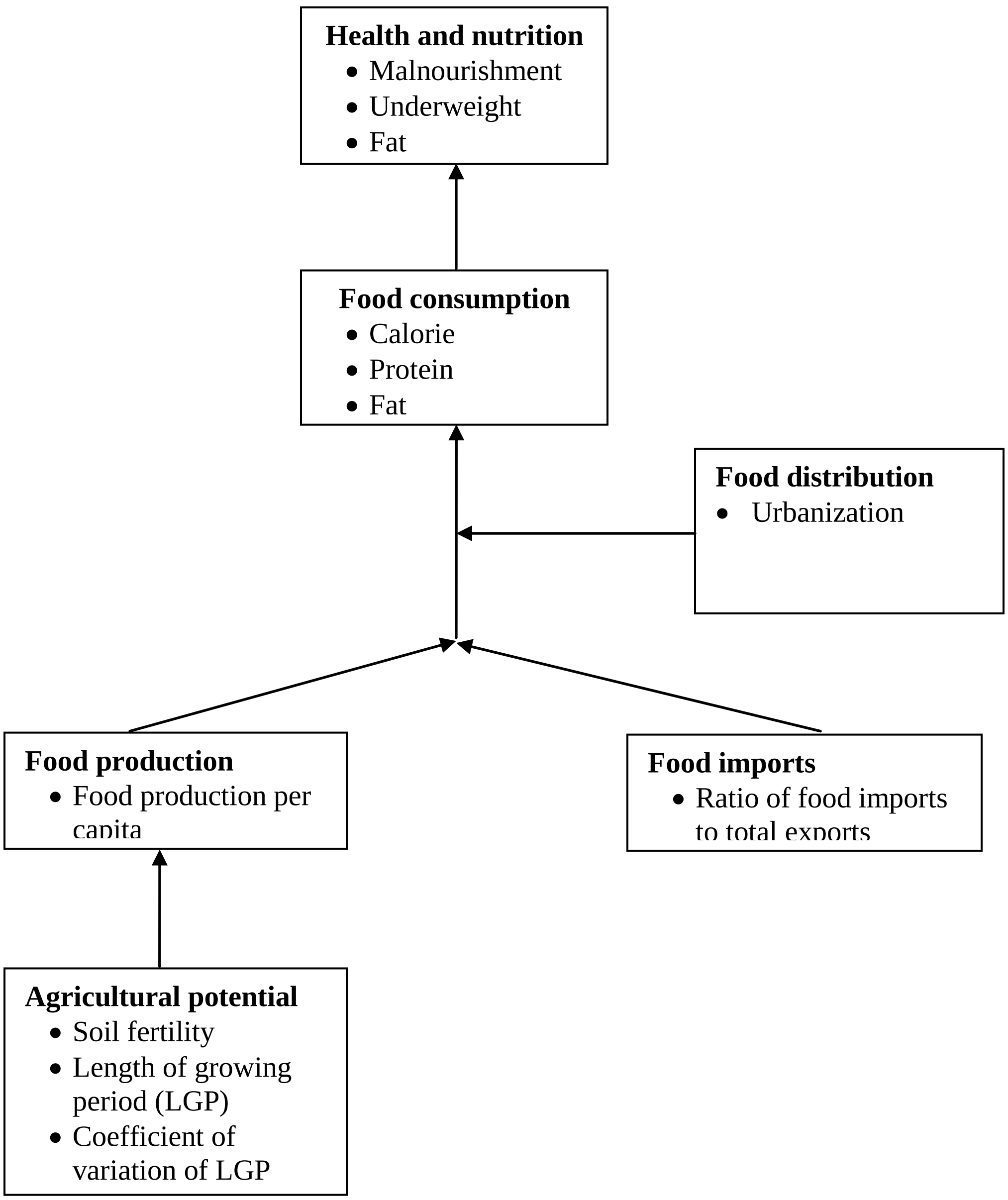
This paper focuses mainly on food availability (domestic production and imports) and utilization (macronutrient consumption) measures. We do not intend to address subnational income or food consumption inequalities, and the results are simply an examination of food security at the national level. We do recognize that there are other possible measures of food security that may lead to different conclusions. Headey and Fan (2008) provide a thorough review of the impact of external shocks (fuel and food price surges) on national food security.

Many studies have found that agriculture has a much greater impact on reducing poverty and improving food security than do other sectors of the economy (Nadav 1996; Majid 2004; Irz et al. 2001). The key contribution of this study is to link food security typologies to indicators of long-term solutions to steady food insecurity—agricultural potential. In countries where agricultural potential is large, the agricultural sector is unquestionably an important instrument to reduce poverty and malnutrition by taking advantage of untapped agricultural potential.

Increased food production would help restore the supply-demand balance at a lower price level. High food prices and the increased incentives they provide present an opportunity for agricultural producers to increase investment and expand production. Initial statistics indicate that the agricultural sector has responded to these greater incentives with increased planting areas and yield, and thus production (FAO 2008a). The need to raise food production should not be limited to current status. Instead, further increases in agricultural production and productivity will be essential to meet further increases in growing future demand. Developing countries need to exploit their potential to increase agricultural production and productivity to achieve food security in both the short and long run through a more conducive policy framework and increased investment in agricultural and rural development. For instance, if soil and temperature conditions are suitable for crop production but rainfall is erratic and volatile in a country, investment in irrigation and water-conservation related technologies would be more effective in improving crop production and productivity. By taking climate and soil conditions into account, policies to exploit potential for increasing agricultural supply can be developed accordingly.

The framework and theoretical logic flow of this exercise on food security typology are illustrated in Figure 1. Broadly defined, food security includes health and nutrition outcomes (such as malnourishment and anthropometric measures of food insecurity) and consumption outcomes (nutrient intake). Health and nutritional outcomes are direct results of consumption outcomes. This study will be focused on consumption outcomes and its sources and potential policy instruments. First, nutritional status in food consumption is identified using three indicators: calorie, protein, and fat intake. Food consumption is jointly determined by domestic food production and food imports from the international market. Agricultural potential, which includes the length of the growing period, the variation of the length of the growing period, and soil quality, is an important precondition for long-term food supply or production. Relevant policies can be applied to improve agricultural potential through proper investment. Trade and trade policies (regional and global), in contrast, influence both national and world food availability, as well as the cost of food imports (including food aid) at the national level. In addition to food supply captured by production and imports, food consumption is also affected by food distribution within the country, proxied by the rate of urbanization. This sequential approach of examining (1) food consumption; (2) production, import, and distribution; and (3) agricultural potential allows us to distinguish outcomes of food security (food consumption) from determinants (food production, import, and distribution) and future potential, providing more targeted policy recommendations for each group.

Figure 1. Structural framework for food security typology



Source: Authors.

Food Security Indicators at the National Level

The indicators used in this study are considered proxies for five dimensions of food security measured at the national level: food consumption, production, trade, distribution, and agricultural potential. For better cross-country comparison and classification, the five dimensions are expressed in nine variables. Average daily calorie, protein, and fat intake per capita are chosen to represent consumption or utilization of food through adequate diet from a nutritional point of view. For sources or availability of sufficient quantity of food, we use annual food production per capita and the ratio of total exports to food imports. Food distribution is proxied as the share of nonagricultural population to capture the inequality between rural and urban residents. Some countries have a comparative advantage over others in terms of agricultural production, which is depicted by three agricultural potential variables: length of growing period (LGP), soil fertility for long-term stability of food supply, and coefficient of variation of LGP for variability or riskiness in food cultivation. These variables are useful in identifying in which countries agriculture can be used as a tool to improve food security. The 175 countries and regions comprise 50 low-, 50 lower-middle-, 34 upper-middle-, and 41 high-income countries, according to the World Bank's definition. Although it would be desirable to assign more indicators to each of the dimensions defined above, data availability is limited, especially for food accessibility indicators. The variables used to capture the five dimensions of food security are summarized in the table below.

Table 1. Five dimensions of food security

Variable	Definition	Year	Source
Food consumption			
Daily calorie intake per capita	Energy intake per capita per day measured in calories	2002-04	FAO (2008b)
Daily protein intake per capita	Protein intake per capita per day measured in grams	2002-04	FAO (2008b)
Daily fat intake per capita	Fat intake per capita per day measured in grams	2002-04	FAO (2008b)
Food production			
Annual food production per capita	Gross sum of all commodities weighted by 1999-2001 average international commodity prices, then divided by total population	2001-2005	FAO (2008b)
Food imports			
Ratio of total exports to food imports	Value of all exported goods and market services divided by food imports	2001-2005	World Bank (2008)
Food distribution			
Share of urban population	Percentage of midyear population of areas defined as urban in total population	2001-2005	World Bank (2008)
Agricultural potential			
Soil without major constraints	Percentage of soil not affected by eight major fertility constraints		FAO (2000)
Length of growing period	Number of days of the year when both natural moisture and temperature conditions are suitable for crop production		Fischer et al. (2001)
Coefficient of variation of length of growing period	Coefficient of variations of length of growing period		Fischer et al. (2001)

Source: Author's compilation.

Food Consumption

Calories, protein, and fat per capita: Three separate variables are used as indicators of average consumption levels at the national level: energy intake per capita per day, measured in calories, and nutrients intake (protein and fat) per capita per day, measured in grams. This analysis uses 2002-2004 average of per capita intake of calorie, protein and fat at national level (FAO 2008b).

Food Production

Food production per capita captures a country's capability to produce food based on current production technology in the country. According to FAO (2008b), food includes all edible commodities containing nutrients that originate in each country, excluding fish. Meat products include all indigenous animals (net exports). Tea and coffee are excluded. *Food production per capita* is calculated in two steps. First, total food production is calculated as the product sum of food production vector and the vector of 1999–2001 average international commodity prices in international dollars. Second, the total food production is divided by national population to get food production per capita, also measured in international dollars. We take 4-year average between 2001 and 2004 to smooth out external shocks like weather.

Food Imports

The ratio of total exports to food imports is defined by dividing total exports by total food imports, averaged over 2001-2004. The total export values are obtained from World Development Indicator (World Bank 2008) and food imports are from FAO (2008b). This variable demonstrates a country's ability to purchase food from international market using its export revenue, considering both availability and accessibility of food in global market. A low ratio suggests the country is more vulnerable to fluctuations in global food price and thus low food security. The advantages of this ratio over traditional imports-only indicators are discussed in details in Diaz-Bonilla et al. (2000).

Food Distribution

Nonagricultural population is an indicator of food distribution across the country. It is calculated as the average share of nonagricultural population in 2001–2004. Ideally, variables measuring equality in income or asset can better represent the accessibility of food in the population. Due to lack of data in income Gini coefficient or poverty headcount across countries, we use the share of nonagricultural people The ratio of urban population indicates the impact of urban consumers, who are increasingly affected by rising food prices as most of them are net food buyers.

Agricultural Potential

Length of growing period (LGP): LGP is defined as the number of days per year in which sufficient water and temperature is available in the soil to support plant growth. The concept of the growing period provides a way of including seasonality in land resource appraisal. In many tropical areas, conditions are too dry during part of the year for crop growth to occur without irrigation, while in temperate climatic regimes crop production in winter is limited by cold temperatures. The growing period defines the number of days of the year when both natural moisture and temperature conditions are suitable for crop production (FAO 1996b). It provides a framework for summarizing temporally variable elements of climate, which can be compared with the requirements and estimated responses of a plant. Such parameters as temperature regime, total rainfall, soil properties, and potential evapotranspiration are more relevant when calculated for the growing period, when they may influence crop growth, rather than averaged over the whole year. LGP is calculated and mapped globally at a resolution of 30 minutes based on spatially interpolated 40-year average climatic data on temperature, humidity, and elevation (New et al. 2000; Fischer et al. 2001). The LGP of a country is the average LGP for all pixels within the country.

Coefficient of variation of LGP: While LGP may represent the relative suitability for growing crops, it fails to capture the temporal year-to-year variation in LGP and the incidence of climatic hazards. The coefficient of variation of LGP is introduced to fill this gap. It is calculated as the ratio of the standard deviation to the mean of LGP, allowing us to compare the scatter of rainfall and temperature variations on a year-to-year basis. Countries with more erratic or irregular rainfall patterns (a coefficient of variation of LGP greater than 1) include some Middle Eastern and North African countries.

Soils without major constraints: This indicator reflects the percentage of soils without major constraints in the total geographical area. Eight major constraints that greatly affect soil management and agricultural production are considered: erosion hazard, aluminum toxicity, shallowness, hydromorphy, salinity and sodicity, low carbon exchange capacity, high phosphorus fixation, and vertic properties (Sanchez et al. 2003). To translate soil characteristics into agronomic constraints, one of the best-known methods, the fertility capability classification (FCC) is used (Sanchez et al. 2003). This characterizes soils by means of a set of fertility constraints, that is, inherent features that present problems to soil management. The FCC criteria were linked with the mapping units of the Soil Map of the World to derive country-level soil constraints. All data reported on inherent soil constraints apply to the total areas of regions or countries, not to their arable land or agricultural land. Thus, for example, the areas shown as having erosion hazard and shallowness include mountainous regions in which little or no attempt at agricultural use is made. A range of soils exist that are not affected by any of the eight major constraints covered above. Based on the method by which these have been identified, they may be referred to simply as soils without major constraints. Soil quality analysis can be used for preliminary assessment of potential development strategies or potential for soil management technology transfer (Nachtergaele and Brinkman 1996).

3. FACTOR ANALYSIS OF FOOD SECURITY

Factor analysis is a statistical method used to describe variability among observed intercorrelated variables in terms of fewer unobservable (latent) variables called factors. The observed variables are modeled as linear combinations of the factors, plus "error" terms. Factor analysis is a form of data dimensionality reduction, and the information gained about the interdependencies can be used later to condense variables into fewer dimensions with a minimum loss of information.

Suppose we have a set of *p* observable random variables $x_1, \dots, x_p$ with means $\mu_1, \dots, \mu_p$. Assume for some unknown constants l_{ij} and *k* unobserved random variables F_{ij}, where $i, j = 1, \dots p$. For $k < p$ we have $x_i - \mu_i = l_{i1}F_1 + \cdots + l_{ip}F_p + \varepsilon_i$.

Here ε_i is independently distributed error terms with zero mean and finite variance, which may vary for different *i*.

Let $V(\varepsilon_i) = \psi_i$, so that we have $COV(\varepsilon_{p\times 1}) = Diag(\psi_1, \dots \psi_p) = \Psi$ and $E(\varepsilon) = \mathbf{0}$. In matrix terms, we have $x - \mu = LF + \epsilon$.

Also, we will impose the following assumptions on *F*:

1. *F* and ϵ are independent.
2. *E(F)* = 0
3. Cov(F) = I(k)

Any solution for the above set of equations following the constraints for *F* is defined as the *factors*, and *L* as the *loading matrix*. Suppose $COV(x_{p\times 1}) = \Sigma_{p\times p}$, then we have $COV(x - \mu) = COV(LF + \epsilon)$, or $\Sigma = LCOV(F)L' + COV(\epsilon) = LL' + \Psi$.

Factor analysis is used to isolate the underlying "factors" that explain the variance of a group of variables. It is an interdependence technique, and the complete set of interdependent relationships is examined. It allows us to reduce the number of variables by combining two or more variables into a single factor. It also assists in the identification of groups of interrelated variables and in seeing how they are related to each other. Factor analysis can be used to identify the hidden dimensions or constructs that may or may not be apparent from direct analysis. However, the usefulness of factor analysis depends on the researcher's ability to develop a complete and accurate set of product attributes. The selection of the variables is crucial because the derived factors will only reflect the structure of the dataset as defined by those variables. If important attributes are missed, the value of the procedure is reduced accordingly. Interpreting factor analysis is based on a heuristic approach, and more than one interpretation can be made of the same data factored the same way. It is not possible to know what the "factors" actually represent without theory or prior knowledge. Also, there is no specification of dependent variables, independent variables, or causality.

Although there have been heated debates over the merits of various methods of conducting factor analysis, a number of leading statisticians have concluded that in practice there is little difference (Velicer and Jackson 1990), since the computations are quite similar despite the differing conceptual bases, especially for datasets in which commonalities are high and/or there are many variables. For our purposes, we will apply principal component analysis, which seeks values of the loadings that bring the estimate of the total commonality as close as possible to the total of the observed variance. The factors produced by principal component analysis are conceptualized as being linear combinations of the variables, and results produced by principal component analysis are not dependent on the method of computation.

Correlation coefficients indicate high correlations among three nutritional indicators: calorie, protein, and fat intake per capita per day. It is suspected that one or more common factors exist among the three variables, and factor analysis is applied to the three measures of nutrition intake. Generally speaking, calorie intake is highly correlated with protein and fat intake, with the correlation coefficient ranging between 0.82 and 0.91. To avoid giving more weight to any one variable because of its unit of measure, variables are standardized to z-scores (subtracting the mean and dividing by the standard deviation). One common factor is extracted from the three variables, and it explains 90 percent of the total variance of the three variables. We name this factor “food security” and it is expressed as the product of factor loading and variables:

$$F = 0.961 * calorie + 0.959 * protein + 0.929 * fat$$

Factor scores are the scores of each country based on the caloric and nutrient intake factors, which are widely used to portray the concept of food security. To compute the food security factor score for a given country, one takes the country’s standardized score on each of the three variables, multiplies it by the corresponding factor loading of the variable for the given factor, and sums these products. Computing factor scores allows us to rank countries for the widely used nutritional or food utilization aspect of food security. In addition, factor scores can be incorporated in subsequent analysis.

The food security score follows a standard normal distribution, with mean equal to 0 and variance equal to 1. The scores range from -2.17 in the Democratic Republic of Congo to 2.14 in the United States. We first split the countries into five groups based on their food security factor scores. Countries with food security factor scores falling below -1 are defined as “Lowest Food Security.” The “Low Food Security” group has factor scores in the -1 to -0.5 range. Countries with factor scores between -0.5 and 0 are considered to be in the “Middle Food Security” category. Factor scores of nutrition consumption between 0 and 1 are labeled as “Upper Middle Food Security.” Finally, countries with food security factor scores above 1 are considered “High Food Security**.”** The means of all nine indicators, as well as gross national income (GNI) values, are summarized for each food security group in Table 2.

Because this study emphasizes the food insecurity issue among countries, we will discuss the first three groups in great detail while only briefly remarking upon the Upper Middle and High Food Security countries.

Table 2. Average value of indicators by food security groups

	Lowest Food Security	Low Food Security	Lower Middle Food Security	Upper Middle Food Security	High Food Security	Sample total
Food security score	-1.4	-0.7	-0.3	0.4	1.6	0.0
Food consumption						
Daily calorie intake per capita	2,026	2,368	2,636	2,977	3,486	2,736
Daily protein intake per capita (grams)	50.3	64.6	75.8	93.1	117.4	82.0
Daily fat intake per capita (grams)	36.9	55.6	66.9	86.5	131.8	77.1
Food production						
Annual food production per capita (2000 international dollars)	94.4	140.2	192.5	264.0	445.1	232.5
Food imports						
Ratio of total exports to food imports	6.7	8.3	10.7	12.7	16.9	11.3
Agricultural potential						
Soil without major constraints (%)	24.2	27.8	34.8	30.8	23.1	28.4
Length of growing period (days)	207.9	191.2	238.2	194.8	203.0	205.0
Coefficient of variation of length of growing period	0.2	0.3	0.2	0.3	0.2	0.2
Urbanization						
Share of nonagricultural population (%)	30.9	49.9	56.7	69.4	82.1	59.4
Gross national income (2007)	395	1181	2663	5906	24407	6837

Source: Authors’ calculations from FAO (2000, 2008b), World Bank (2008), New et al. (2000), and Fischer et al. (2001).

4. TYPOLOGY ANALYSIS

We will employ a sequential method to generate a food security profile for the 175 countries included in this study. First, countries within each food security group are further divided according to their trade security level. The countries whose food imports account for more than 10 percent of total export earnings are categorized as trade insecure, while countries who spend less than 10 percent of total exports on importing food from world markets are trade secure. Second, countries are further organized according to their food production level. If a country's food production per capita per year is below the sample mean of $232 in 1999–2001 international dollars, it is classified as a low food production country. Otherwise, the country is high food production. Finally, we arrange countries within each trade and production subgroup into four sets, based on their agronomic conditions: countries with high soil fertility and favorable climate, countries with high soil fertility and unfavorable climate, countries with low soil fertility and favorable climate, and countries with low soil fertility and unfavorable climate. It is possible that not all subgroups exist within each food security group. For example, there are no trade-insecure countries in the High Food Security group, and no high food production countries in the Lowest Food Security group. In the end, there are 53 country groupings.

Table 3 lists the countries based on their food security status and conditions of climate and soil fertility. The level of food security is defined as Lowest, Low, Middle, Upper Middle, and High, and it increases as we move down the table. For example, the first panel lists the Lowest Food Security countries, classified in two subgroups: the trade secure and low production subgroup and the trade insecure and low production subgroup. These countries are first grouped based on their soil fertility conditions, using the sign of the z-score of the percentage of soil without major fertility constraints. "High soil fertility" refers to positive z-scores for the percentage of soil fertility, and "low soil fertility" refers to negative z-scores. Within each soil group, countries are further disaggregated based on their climate conditions. We define "favorable climate" as positive z-scores for temperature and rainfall conditions and "unfavorable climate" as negative z-scores. Countries in the Low Food Security group are listed in the next panel of two rows, followed by the panels of the Middle and Upper Middle Food Security countries. The last panel of four rows includes High Food Security countries. Countries can also be classified based on food security status and geographic location. The Lowest and Low Food Security countries are overwhelmingly clustered in Sub-Saharan Africa. Most Latin American countries fall into the Middle and Upper Middle Food Security groups, and the majority of Western European and North American countries belong to the High Food Security group.

Table 3. Food security typology profile summary

			Low soil fertility		High soil fertility	
			Unfavorable climate	Favorable climate	Unfavorable climate	Favorable climate
Lowest Food Security	Trade insecure	Low food production	Eritrea, Kenya, Niger, Tanzania, Yemen, Zambia	Burundi, Central African Republic, Democratic Republic of Congo, Liberia, Rwanda, Sierra Leone, Solomon Island, Uganda	Democratic Republic of Korea, Ethiopia, Malawi, Mozambique	Bangladesh, Comoros, Guinea, Haiti, Madagascar, Togo
	Trade secure	Low food production	Angola, Tajikistan	Cambodia, Laos, Republic of Congo	Zimbabwe	Swaziland
Low Food Security	Trade insecure	Low food production	Djibouti, Guinea-Bissau, Mali, Namibia, Pakistan, Palestine, Sudan	Cameroon, Côte d'Ivoire, Ghana, Nepal	Armenia, Benin, Gambia, Senegal	Dominican Republic, Guatemala, Honduras, Nicaragua, Sri Lanka
	Trade secure	Low food production	Bolivia, Botswana, Chad, Peru	Colombia, Venezuela, Vietnam	India, Lesotho	Panama, Philippines
Middle Food Security	Trade insecure	High food production		Belize, Guyana, Paraguay	Moldova	Dominica, Vanuatu
		Low food production	Jordan, Mongolia, Timor-Leste	Suriname	Burkina Faso	Antigua and Barbuda, Bosnia and Herzegovina, El Salvador, Georgia, Jamaica, San Tome and Principe
	Trade secure	High food production		Thailand		Costa Rica, Ecuador
		Low food production	Uzbekistan	Indonesia, Myanmar, Netherlands Antilles	Azerbaijan, Nigeria	Gabon, Seychelles, St. Vincent and Grenadine

Table 3. Continued

Upper Middle Food Security	Trade insecure	High food production	Kyrgyzstan, Lebanon		Belarus, Latvia, Macedonia, Syria	Albania
		Low food production	Algeria, Egypt, Mauritania, Saudi Arabia, South Africa		Cape Verde, Mauritius, Morocco	Bahamas, Barbados, Cuba, Fiji, Grenada, Kiribati, Maldives, New Caledonia, Samoa, St. Kitts and Nevis, St. Lucia
	Trade secure	High food production	Chile, China, Estonia, Iran, Kazakhstan, Turkmenistan	Brazil, Malaysia, New Zealand, Slovakia	Argentina, Bulgaria, Russia, Turkey, Ukraine	Croatia, Serbia and Montenegro, Slovenia, Uruguay
		Low food production	Kuwait, Libya, Mexico, Tunisia	Brunei, Trinidad and Tobago		Japan, Republic of Korea
High Food Security	Trade insecure	High food production	Spain	Portugal	Cyprus, Greece	
		Low food production				French Polynesia
	Trade secure	High food production	Australia, Canada, Finland, Iceland, Israel, Norway, Sweden, Switzerland	Austria, Germany, Hungary, Ireland, Italy, Luxembourg, Netherlands, Poland, United Kingdom	Lithuania, United States	Belgium, Czech Republic, Denmark, France, Romania
		Low food production	United Arab Emirates			Malta

Source: Authors' calculations from FAO (2000, 2008b), World Bank (2008), New et al. (2000), and Fischer et al. (2001).

Lowest Food Security Group

The Lowest Food Security group contains 31 countries. Countries in this group all have food security factor scores below -1.0 and below, and they suffer from the lowest levels of daily food intake measured in calories (2,026), protein (50.3 grams), and fat (36.9 grams) per capita. These countries have nutrition indicators that are all below the -0.5 threshold of their standardized z-score values. They show the lowest levels of food production per capita ($94.4 in 1999–2001 international dollars) and have the lowest per capita income (a GNI per capita of only $395). Food imports for the group on average amount to more than 15 percent of total exports, and countries are predominately rural (only 31 percent of the population is urban). Generally speaking, policies improving agricultural productivity and rural employment tend to improve food security in the rural areas. All but one country (Swaziland) are classified as low-income economies by the World Bank. Of the 31 countries in this group, only 7 countries spend less than 10 percent of foreign exchange earnings on food imports: Angola, Cambodia, Laos, Republic of Congo, Swaziland, Tajikistan, and Zimbabwe.

Twenty-two countries in this group are located in Sub-Saharan Africa, of which 18 countries are trade insecure: Burundi, Central African Republic, Comoros, Democratic Republic of Congo, Eritrea, Ethiopia, Guinea, Kenya, Liberia, Madagascar, Malawi, Mozambique, Niger, Rwanda, Sierra Leone, Tanzania, Uganda, and Zambia. Four countries in East Asia and the Pacific Rim are also classified as most food insecure: Cambodia, Democratic Republic of Korea, Laos, and Solomon Islands. In addition, Bangladesh in South Asia, Yemen in the Middle East, and Haiti in Latin America and the Caribbean are also in the Lowest Food Security group. Historically, a major source of food insecurity is conflict, and the majority of countries in this group have experienced recent conflict.

Soil fertility is low in 19 countries but climate is favorable for crop cultivation in 11 of them. Eight countries are endowed with low soil fertility and unfavorable climate, as indicated in Table 3. More than half of the countries in the Lowest Food Security group (17 countries) enjoy favorable climate, and soil fertility is favorable for agricultural production in 6 countries. However, countries in this group do not generate enough food supply, and average annual per capita food production is less than $170, despite favorable climate and soil conditions.

Low Food Security Group

This group has low nutrition consumption but is better off than the Lowest Food Security group, with average daily consumption of 2,368 calories, 64.6 grams of protein, and 55.6 grams of fat. Food imports still account for a significant share (near 12 percent) of total export earnings, indicating heavy reliance on the international market and food aid. About one-third of the countries are trade secure. The urbanization ratio is significantly above that of the Lowest Food Security group, and about half of this group's population lives in rural areas. Countries in the Low Food Security group generally are all low food producing countries, and annual food production per capita averages about $140.

This group includes 31 countries, 18 of which are low-income economies. There are 14 Sub-Saharan countries in this group, of which 12 are low-income countries (all except Botswana and Namibia): Benin, Cameroon, Chad, Côte d'Ivoire, Gambia, Ghana, Guinea-Bissau, Lesotho, Mali, Senegal, Sudan, and Togo. Nine countries in Latin America and the Caribbean fall into this group as well: Bolivia, Colombia, Dominican Republic, Guatemala, Honduras, Nicaragua, Panama, Peru, and Venezuela. India, Nepal, Pakistan, and Sri Lanka are also Low Food Security countries. This group also includes the Philippines and Vietnam in East Asia, Armenia in Eastern Europe, and Djibouti and Palestine in the Middle East and North Africa.

It is worth noting that most Latin American and Caribbean countries in this group are far less rural than are other food-vulnerable countries in this group. In fact, on average more than 68 percent of the population in the Latin American and Caribbean countries in the Low Food Security group is classified as urban. This raises the issue of urban food insecurity, which has its own special characteristics. Improved food productivity can benefit both rural and urban population. Incomes of rural producers can be increased while lower food price relief the burden of food among urban residents.

As with the Lowest Food Security group, countries in this group are present in all four climate and soil condition combinations. Climate and soil fertility conditions are detrimental for food production in 11 countries: Bolivia, Botswana, Chad, Djibouti, Guinea-Bissau, Namibia, Pakistan, Palestine, Peru, Mali, and Sudan, where deserts account for a substantial share of land area. In contrast, 8 countries enjoy highly fertile soil and favorable climate. They are located in tropical areas, including 5 countries in Latin America and the Caribbean (Dominican Republic, Guatemala, Honduras, Nicaragua, and Panama), 1 in Sub-Saharan Africa (Togo), 1 in East Asia and the Pacific (Philippines), and 1 in South Asia (Sri Lanka).

Middle Food Security Group

The Middle Food Security group countries have food utilization indicator z-scores in the -0.5 to 0 range, although there are some deviations, mostly toward the values above +0.5 or below -0.5. All these countries show levels of per capita food consumption and production above those of the Low Food Security group. An average person consumes 2,636 calories, 75.8 grams of protein, and 66.9 grams of fat per day. Annual per capita food production increases to $192. Countries in this group tend to be more trade secure and spend less than 10 percent of total export income on food imports. More than 56 percent of the population is urban. Of the 29 members of this group, 12 are from Latin American and the Caribbean, 5 from Sub-Saharan Africa, 6 from East Asia and the Pacific, 5 from Eastern Europe and Central Asia, and 1 from the Middle East.

Table 3 indicates that higher-than-average food production is associated with benign climate and fertile soil in this group. Favorable climate is registered in 8 out of 9 high food production countries, including Costa Rica, Ecuador, Paraguay, and Thailand. Several large countries (in terms of land area) have low food production due to unfavorable climates: Azerbaijan, Burkina Faso, Jordan, Mongolia, Nigeria, and Uzbekistan. There are also countries that have favorable climates but produce less than the average amount food per capita: Bosnia and Herzegovina, El Salvador, Gabon, Georgia, Indonesia, Jamaica, and Myanmar.

Many small islands, scattered in the Caribbean and the Pacific Ocean, are classified in this group, which requires some further analysis because the levels of trade stress are the highest in some of these individual countries. The level of trade stress is an issue for countries such as Antigua and Barbuda, Belize, Dominica, Guyana, Jamaica, Suriname, and Vanuatu. For most of these island countries, food imports normally account for 20–30 percent of total exports, as most of them have little arable land and thus have to depend heavily on imported food shipments. Although these countries have a high to very high food import bill, they should not be classified as food insecure. In terms of trade stress, the countries mentioned above are vulnerable or worse off than some less-food-secure countries, but they also have far higher levels of consumption of calories and nutrition. In addition, these countries are far less rural than most food-insecure countries, and most of them are classified as low- or upper-middle-income countries by the World Bank. Therefore, these trade-stressed countries are classified by the factor analysis algorithm in the Middle Food Security group.

Upper Middle Food Security Group

The Upper Middle Food Security group countries have their food security z-score indicators in the 0 to 1 range. The levels of nutrition consumption are higher than those of their counterparts in the Middle Food Security group, with an average per capita daily intake of 2,977 calories, 93.1 grams of protein, and 86.5 grams of fat. Per capita food production in the Upper Middle Food Security group is higher than that of the Middle Food Security group, but countries in this group exhibit higher annual food production per capita, at $445, despite lower soil fertility and unfavorable growing conditions. In the Upper Middle Food Security group, major players in food production are concentrated in Eastern Europe and Central Asia (16 countries) and Latin America and the Caribbean (5 countries), in addition to China, Malaysia, and New

Zealand in East Asia and the Pacific Rim. Currently, South Africa is the solo significant food exporter in Sub-Saharan Africa in this group.

This group stands out for high soil quality—some of the world's most fertile soil, without any major fertility constraints, is located in countries within this group. Many countries in this category have great potential to significantly increase their food production and provide a resilient supply for the world market. Among the countries enjoying favorable climate and good soil conditions, many are major food producers located in Eastern Europe, Central Asia, and South America. No trade-secure country falls into the combination of favorable climate and low soil fertility category. Among 17 countries with barren soil and inclement climate, food production is higher than average in 8 countries: Chile, China, Estonia, Iran, Kazakhstan, Kyrgyzstan, Lebanon, and Turkmenistan. Additionally, 4 more countries with low soil fertility but favorable climate are high food production countries: Brazil, Malaysia, New Zealand, and Slovakia. Of the 14 high food production countries where soil is generally rich, adverse climate exists in 9 countries: Argentina, Belarus, Bulgaria, Latvia, Macedonia, Russia, Syria, Turkey, and Ukraine. Only 5 high food production countries are blessed with both favorable climate and high soil fertility: Albania, Croatia, Serbia and Montenegro, Slovenia, and Uruguay. The many countries with high food production in this group indicate that difficult natural endowment for crop cultivation cannot necessarily be the single or predominant determinant of agricultural production or food security status, and investment in the agricultural sector could improve and overcome the agronomical constraints in countries without beneficial natural conditions.

High Food Security Group

The last panel of Table 3 includes countries with food security factor scores above the +1 value, which translates into an average daily consumption of calories, protein, and fat in excess of 3,486, 117.4 grams, and 131.8 grams, respectively. Annual food production per capita hovers far above that of any other group (above $445), and the food import bill is less than 6 percent of total exports (i.e., these countries are mostly trade secure). Most countries are very urban (more than 82 percent of total population). There are 5 trade-insecure countries in this group, but their high levels of food consumption and domestic production, have provided enough buffers to achieve food security under any likely event, domestic or international. All of the 33 countries in the High Food Security group are classified as high income by the World Bank, with the exception of 3 upper-middle-income countries (Lithuania, Poland, and Romania).

5. EVOLUTION OF FOOD SECURITY

This section compares the five food security indicators—calorie intake per capita, protein intake per capita, food production per capita, ratio of total exports to food imports, and share of nonagricultural population—that are available for both the study by Diaz-Bonilla et al. (2000) and this study. Table 4 presents the percentage growth in these variables over an eight-year period, from 1993–1997 to 2001–2005 (five-year average); positive growth means improved food security. The five indicators all grow at different rates, with food production and protein intake growing most rapidly and calorie intake growing most slowly.

Table 4. Annual average percentage growth rate of food security indicators from 1993–1997 to 2001–2005

	Calorie intake per capita	Protein intake per capita	Food production per capita	Ratio of total exports to food imports	Share of non-agricultural population
Lowest Food Security group	0.3	0.7	1.5	0.5	1.5
Low Food Security group	0.3	1.5	1.8	2.6	0.4
Middle Food Security group	0.4	1.4	0.2	2.5	1.1
Upper Middle Food Security group	0.3	1.6	2.1	0.8	0.7
High Food Security group	0.6	1.7	1.0	4.0	0.0
Total	0.4	1.5	1.4	2.1	0.7

Source: Author's calculations from FAO (2008b), World Bank (2008), and Diaz-Bonilla et al. (2000).

In terms of calorie intake, all groups registered positive growth, but the High Food Security group grew faster than the Lowest and Low Food Security groups. Protein intake grew healthily across all groups, and generally the growth rate of protein intake was higher than that of energy intake. But protein intake grew most slowly in the Lowest Food Security group, at 0.6 percent per year, compared to a robust 1.5 percent or higher in other groups. There is a trend of urbanization, which is more manifest in the Lowest and Middle Food Security countries, which witnessed the share of urban population increasing by 1.1–1.2 percent annually.

Food production increased universally, especially in the Upper Middle Food Security countries. Several countries with favorable climate or fertile soil registered dramatic increases in per capita food production (by more than 50 percent within a decade), including Armenia, Azerbaijan, Belarus, Cuba, Ghana, Laos, Malaysia, Rwanda, and Vietnam. However, food production per capita dropped more than 20 percent in some countries with unfavorable agricultural environments (Botswana and Namibia) or tropical islands (Antigua and Barbuda, Saint Lucia, Saint Vincent and Grenadines, and Vanuatu,), as well as three Sub-Saharan African countries: Democratic Republic of Congo, Eritrea, and Senegal. In fact, among the countries that experienced negative growth in per capita food production, 23 out of 41 are located in Sub-Saharan Africa, and 9 in Latin America and the Caribbean.

The trade variable had the largest volatility, with the annual growth rate ranging from -20.6 percent in the Bahamas to more than 31.8 percent in Uzbekistan. The average share of food imports in total exports decreased in all groups except the Lowest Food Security group, indicating a deteriorating trade balance in the most vulnerable countries. Combined with slow growth in per capita food production and high urbanization, it implies that the trade-stressed Lowest Food Security countries have observed an increased burden of imported-food bill while facing a quickly urbanizing population. It is important to note that aggregation by income level could mask the vast differences among countries within the same income level.

Among the countries in the Lowest Food Security group, most exhibited some improvement in at least one of the five temporal indicators between the mid-1990s and early 2000s. Of the 30 least-food-secure countries, 3 countries improved in all 5 indicators: Cambodia, Malawi, and Mozambique. Additionally, 11 countries gained in 4 out of 5 indicators. Two countries showed the completely opposite trend: food consumption and production per capita declined, trade position deteriorated, and urbanization reversed, indicating that the consumption, distribution, and availability of food plummeted. Both countries, the Democratic Republic of Congo and Zimbabwe, are located in Sub-Saharan Africa.

Seventeen out of 30 countries in the Lowest Food Security group observed higher per capita food production, with growth of more than 4 percent per year registered in Laos, Malawi, Rwanda, and Uganda. Additionally, food production net of population growth grew more than 2.4 percent per year in 7 countries: Angola, Bangladesh, Cambodia, Central African Republic, Guinea, Kenya, and Mozambique, and grew 1–2 percent annually in Haiti, Liberia, Niger, and Tajikistan. Despite the encouraging progress in these countries, per capita food production decreased in a dozen of the Lowest Food Security countries. Annual per capita food production fell by more than 1 percent per year in Burundi, Comoros, Democratic Republic of Congo, Eritrea, Ethiopia, Madagascar, Republic of Congo, Togo, Zambia, and Zimbabwe. It is alarming to recognize that millions of people are facing a dwindling domestic food supply, which could be attributed to adverse climate conditions, conflicts, and poor agricultural policies.

6. DISCUSSION AND CONCLUSION

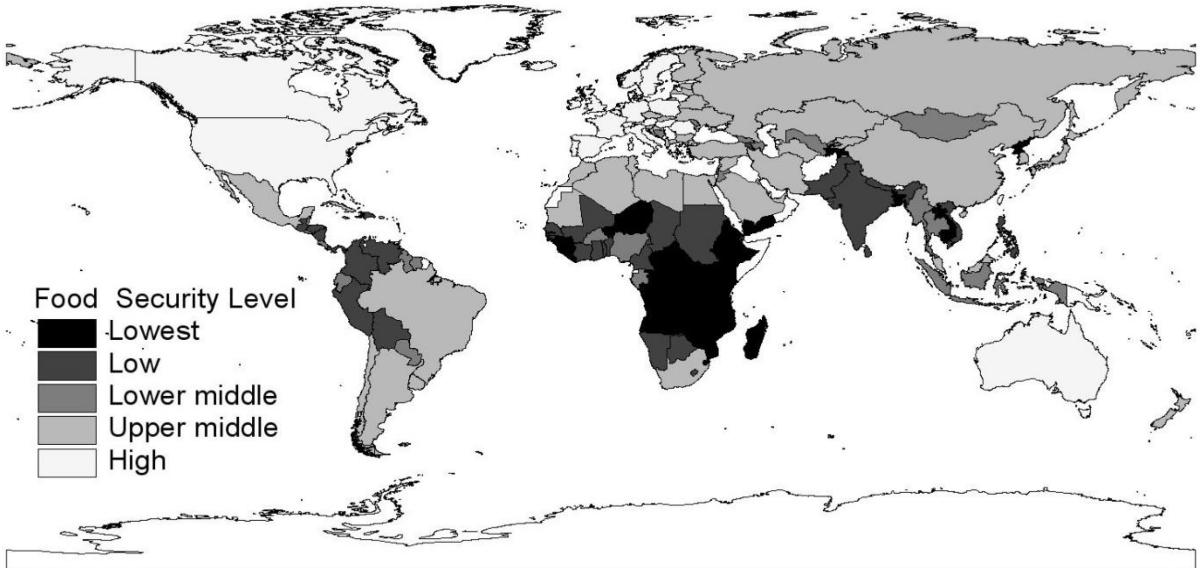
This study conducts a factor and sequential typology analysis to categorize groups of countries according to five measures of food security: consumption, production, imports, distribution, and agricultural potential. The analysis first identifies five distinct food security groups characterized by food intake, then further splits these groups based on the various measures of food production, trade security, and agricultural potential. Highlighting groups of countries with similarities in their food security profiles, as measured by the variables considered here, allows a more differentiated analysis of possible food-security situations. This classificatory exercise is also relevant for the grouping of countries in terms of their possible investments, policy interventions, and trade positions.

The results address the two issues identified in the introduction: first, this analysis reports that developing countries in all the food security groups except for the High Food Security group. Our results confirm the finding of Diaz-Bonilla et al. (2000) that using the phrase "developing countries" in the discussion of food security is not very meaningful. Second, appropriate policies should be tailored for each food security group.

The categories established by per capita income level as defined by the World Bank, however, are more aligned with our definition of food security groups: low-income economies fall predominantly into the Lowest Food Security group with the lowest food consumption indicators. Of the 50 low-income countries included in this study, all fall into the Lowest or Low Food Security groups except Burkina Faso, Kyrgyzstan, Mauritania, Myanmar, Nigeria, San Tome and Principe, Uzbekistan, and Vietnam. At the same time, all high-income countries belong to the High Food Security group.

Figure 2 presents the regional distribution of the Lowest, Low, Middle, Upper Middle, and High Food Security groups. Sub-Saharan Africa dominates the Lowest and Low Food Security groups, especially the Lowest group. This is consistent with the FAO (2008a) report stating that of 39 countries that experienced serious food emergencies and required external assistance to deal with critical food insecurity in 2007/08, 25 are in Africa. One South Asian country is in the Lowest Food Security group (Bangladesh), and 4 are in the Low Food Security group (India, Nepal, Pakistan, and Sri Lanka). Central American and Caribbean countries are mostly clustered in the Low and Middle Food Security groups, while several large South American economies fall into the Upper Middle Food Security group (Argentina, Brazil, Chile, and Uruguay). Countries in the Middle East and North Africa are concentrated in the Upper Middle Food Security group, except for Yemen and Jordan in the lower food security groups. Eastern European and Central Asian countries congregate mostly in the Middle and Upper Middle Food Security groups, while all countries in Western Europe and North America are in the High Food Security group. The results of this study should allow countries within the same food security category to identify food security solutions by further exploring the synergies of cross-country study and learning from each other's successes and failures. The study also encourages conventional subnational analyses to be more integrated into regional analyses based on food-security-related issues.

Figure 2. World food security level



Source: Authors' calculation based on FAO (2008b).

Gentilini and Webb (2008) built a composite indicator to measure progress toward achieving the poverty and hunger MDG in 135 countries. Using nonparametric approaches, they found that poverty and hunger were related but distinct concepts, and the resulting ranking of poverty and hunger indexes (PHIs) confirms this typology analysis. Of the 28 countries with low PHIs, almost all fall in the Lowest or Low Food Security groups in our study. In fact, 13 out of the 15 countries with the lowest PHI scores are identified as Lowest Food Security countries.

The Global Hunger Index 2003 (Wiesmann 2006) ranks 119 countries in the world, based on three equally weighted indicators: the proportion of people who are food-energy deficient (share of the population with inadequate dietary energy intake) as estimated by FAO, the prevalence of underweight in children under the age of five as compiled by the World Health Organization (the proportion of children suffering from weight loss and/or reduced growth), and the under-five mortality rate as reported by the United Nations Children's Fund. The results show that most of the countries with low hunger indexes (poor performance in alleviating hunger) are in Sub-Saharan Africa and South Asia. There are a few exceptions to this regional pattern, and several countries have high hunger scores (at the alarming or extremely alarming level): Haiti in the Caribbean; Yemen in Middle East; Tajikistan in Central Asia; Cambodia, Laos, and Timor-Leste in Southeast Asia; and Nepal in South Asia. The findings based on the Global Hunger Index are consistent with the Lowest and Low Food Security groups defined in this study.

The second issue of policy design is also very relevant. The classification of food-insecure countries presented here would help define more precisely the group of countries that are vulnerable to food-security problems, and thus enable more targeted policies in representative countries. Stakeholders could design country- and region-specific policies to overcome constricting factors in promoting agriculture production. In order to achieve food security, developing countries with favorable land and water conditions need to exploit their potential to increase agricultural production and productivity through a more conductive policy framework and increased investment in agricultural and rural development. This approach allows decisionmakers to mobilize and use resources more effectively and efficiently in order to achieve development and food security goals.

For instance, in many Lowest and Low Food Security countries, the climate is beneficial for crop production but the soil is plagued by major constraints such as aluminum toxicity. The supply response to modern technology will be poor for most crops and cultivars as long as the soil remains strongly acidic from aluminum toxicity. This could be corrected by choosing the correct soil management technology (such as liming). Most Sub-Saharan African countries fall into this category: Burundi, Cameroon, Central African Republic, Côte d'Ivoire, Democratic Republic of Congo, Ghana, Liberia, Republic of Congo, Rwanda, Sierra Leone, and Uganda. Several countries scattered in East Asia (Cambodia, Laos, and Vietnam), South Asia (Nepal), and Latin America and the Caribbean (Colombia and Venezuela) are also in need of proper soil management technologies. A regional study of agricultural productivity and agricultural conditions in southern Africa suggested similar prescriptions of soil fertility maintenance and enhancement for profitable chemical fertilizer usage (Abalu and Hassan 1998). In contrast, if soil and climate conditions are suitable for crop production but rainfall is erratic and volatile in a country, investment in irrigation and water-reservation-related technologies is shown to be more effective in improving crop output and yield. Many of the Lowest and Low Food Security countries could increase food supply by targeting stable water sources for agricultural production: Armenia, Benin, Democratic Republic of Korea, Ethiopia, Gambia, India, Lesotho, Malawi, Mozambique, Senegal, and Zimbabwe. In food-importing countries such as the Gulf states, with both arable land and water constraints, improved terms of trade for grain imports are a more feasible and efficient solution than extremely high investment in the agricultural sector. Countries with fertile arable land and favorable climate are in an excellent position to improve national food security by taking advantage of their agricultural potential with minimal investment requirement. The Lowest and Low Food Security countries in this category include Bangladesh, Comoros, Dominican Republic, Guatemala, Guinea, Haiti, Honduras, Madagascar, Nicaragua, Panama, Philippines, Sri Lanka, Swaziland, and Togo. Globally, in countries with supreme soil and moderate temperature conditions, such as Eastern European and Central Asian countries, policies to promote cereal production are one way to exploit the countries' comparative advantages in food production in the international market.

Not only is an increase in investment in agriculture needed, but the right focus must be found for this investment. A coordinated response should emphasize the need to deliver location-specific technologies that are tailored to agroecological characteristics and production systems, aiming at both productivity and sustainability. To achieve greater development and food security, donors need to scale up and prioritize aid for agriculture to overcome the inability of local governments to provide the necessary infusion of capital.

This study has its limits. First, it is a simply grouping practice considering spatial variations in food security, but it does not take into account of the source of this variation. It is important to examine the impacts of institutional and external shocks over time, considering both policy variables and exogenous events. These shocks that disrupt agricultural production in a country and compromise its food security include adverse weather, political instability, and governance. Relevant policy interventions relating to this aspect can be developed for different groups of countries. Second, the 2007-08 food price surge is not included in this analysis. There is still little research on the negative impacts of high food prices and elevated price fluctuations on nutrition, poverty and food security and national or regional level. Third, as mentioned in the discussion of the theoretical framework, health and nutrition issues are also an important aspect of food security, and food security typology can be further extended to include the health and nutrition dimension in our study.

REFERENCES

Abalu, G., and R. Hassan. 1998. Agricultural productivity and natural resource use in southern Africa. *Food Policy* 23 (6): 477–490.

Clay, E. 2002. Food security: Concepts and measurement. In *Trade reforms and food security: Conceptualising the linkages*. Rome: Food and Agriculture Organization of the United Nations.

Diaz-Bonilla, E., M. Thomas, S. Robinson, and A. Cattaneo. 2000. *Food security and trade negotiations in the World Trade Organization: A cluster analysis of country groups*. Trade and Macroeconomics Division Discussion Paper 59. Washington, D.C.: International Food Policy Research Institute.

FAO (Food and Agriculture Organization of the United Nations). 1996a. *Rome declaration on world food security and World Food Summit plan of action*. Rome.

________. 1996b. *Agro-ecological zoning guidelines*. FAO Soils Bulletin 73. Rome.

________. 2000. *Land resource potential and constraints at regional and country levels*. World Soil Resources Report 90. Rome.

________. 2008a. *The state of food insecurity in the world 2008: High food prices and food security—threats and opportunities*. Rome.

_________. 2008b. FAOSTAT. Rome. <http://faostat.fao.org/>. Accessed May 2008.

_________. 2009. *Assessment of the world food security and nutrition situation*. Committee on World Food Security, 34th Session. Rome.

Fischer, G.,M. Shah, H. Velthuizen, and F. Nachtergaele 2001. *Global agro-ecological assessment for agriculture in the 21st century*. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Gentilini, U., and P. Webb. 2008. How are we doing on poverty and hunger reduction? A new measure of country performance. *Food Policy* 33 (6): 521–532.

Headey, D., and S. Fan. 2008. *Anatomy of a crisis: The causes and consequences of surging food prices*. Discussion Paper 831. Washington, D.C.: International Food Policy Research Institute.

Heidhues, F., A. Atsain, H. Nyangito, M. Padilla, G. Ghersi, and J. Le Vallée. 2004. *Development strategies and food and nutrition security in Africa: An assessment*. 2020 Discussion Paper No. 38. Washington, D.C.: International Food Policy Research Institute.

Irz, X., L. Lin, C. Thirtle, and S. Wiggins. 2001. Agricultural productivity growth and poverty alleviation. *Development Policy Review* 19 (4): 449–466.

Majid, N. 2004. *Reaching Millennium Goals: How well does agricultural productivity growth reduce poverty?* Employment Strategy Paper 2004 No. 12. Geneva: International Labor Organization.

Nachtergaele, F., and R. B. Brinkman. 1996. Identification of analogous land for agrotechnology transfer in the savannah zones of the developing world. *Integrated Crop Management Series* 1: 29–41.

Nadav, C. 1996. *Nutritional thresholds and growth*. Beer-Sheva, Israel: Department of Economics, Ben-Gurion University.

New, M., M. Hulme and P. D. Jones. 2000. Representing twentieth-century space–time climate variability. Part II: Development of 1901–96 monthly grids of terrestrial surface climate. *Journal of Climate* 13 (7): 2217–2238.

Sanchez, P. A., C. A. Palm, and S. W. Buol. 2003. Fertility capability soil classification: A tool to help assess soil quality in the tropics. *Geoderma* 114: 157–185.

Velicer, W. F., and D. N. Jackson. 1990. Component analysis versus common factor analysis: Some issues in selecting an appropriate procedure. *Multivariate Behavioral Research* 25 (1): 1–28.

von Braun, J., Ahmed, A., Asenso-Okyere, K., Fan, S., Gulati, A., Hoddinott, J., Pandya-Lorch, R., Rosegrant, M. W., Ruel, M., Torero, M., van Rheenen, T., von Grebmer, K., 2008. High food prices: The what, who, and how of proposed policy actions. Policy Brief May 2008. Washington, D.C.: International Food Policy Research Institute.

Wiesmann, D. 2006. *A global hunger index: Measurement concept, ranking of countries, and trends*. Food Consumption and Nutrition Division Discussion Paper 212. Washington, D.C.: International Food Policy Research Institute.

World Bank. 2008. *World Development Indicators*. Washington, D.C.

Zhang, X., M. Rockmore, and J. Chamberlin. 2007. *A typology for vulnerability and agriculture in Sub-Saharan Africa*. Discussion Paper 734. Washington, D.C.: International Food Policy Research Institute.

RECENT IFPRI DISCUSSION PAPERS

For earlier discussion papers, please go to http://www.ifpri.org/category/publication-type/discussion-papers.
All discussion papers can be downloaded free of charge.

944. *Paving the way for development? The impact of transport infrastructure on agricultural production and poverty reduction in the Democratic Republic of Congo.* John Ulimwengu, Jose Funes, Derek Headey, and Liangzhi You, 2009.

943. *Formal–informal economy linkages and unemployment in South Africa*. Rob Davies and James Thurlow, 2009.

942. *Recent food prices movements: A time series analysis*. Bryce Cooke and Miguel Robles, 2009.

941. *Decentralization, agricultural services and determinants of input use in Nigeria*. Kamiljon T. Akramov, 2009.

940. *How important are peer effects in group lending? Estimating a static game of incomplete information.* Shanjun Li, Yanyan Liu, and Klaus Deininger, 2009.

939. *Rice production responses in Cambodia*. Bingxin Yu and Shenggen Fan, 2009.

938. *A latent class approach to investigating consumer demand for genetically modified staple food in a developing country: The case of gm bananas in Uganda*. Enoch Kikulwe, Ekin Birol, Justus Wesseler, and José Falck-Zepeda, 2009.

937. *Cluster-based industrialization in China: Financing and performance.* Cheryl Long and Xiaobo Zhang, 2009.

936. *Sensitivity of welfare effects estimated by equilibrium displacement model: A biological productivity growth for semisubsistence crops in Sub-Sahara African market with high transaction costs*. Hiroyuki Takeshima, 2009.

935. *Assessing household vulnerability to climate change: The case of farmers in the Nile Basin of Ethiopia*. Temesgen T. Deressa, Rashid M. Hassan, and Claudia Ringler, 2009.

934. *Do external grants to district governments discourage own-revenue generation?: A look at local public finance dynamics in Ghana*. Tewodaj Mogues, Samuel Benin, and Godsway Cudjoe, 2009.

933. *Impacts of prenatal and environmental factors on child growth: Evidence from Indonesia*. Futoshi Yamauchi, Katsuhiko Higuchi, and Rita Nur Suhaeti, 2009.

932. R*ich consumers and poor producers: Quality and rent distribution in global value chains*. Johan F.M. Swinnen and Anneleen Vandeplas, 2009.

931. *Economic growth and distribution of income: A Growth model to fit Ghanaian data. Harumi* T. Nelson , Terry L. Roe, and Xinshen Diao, 2009.

930. *Trade liberalization, poverty, and food security in India*. Manoj Panda and A. Ganesh-Kumar, 2009.

929. *Improving the proof: Evolution of and emerging trends in impact assessment methods and approaches in agricultural development.* Mywish K. Maredia, 2009.

928. *Improving diet quality and micronutrient nutrition: Homestead food production in Bangladesh.* Lora Iannotti, Kenda Cunningham, and Marie Ruel, 2009.

927. *Land-tenure policy reforms: Decollectivization and the Doi Moi System in Vietnam.* Michael Kirk and Tuan Nguyen, 2009.

926. *"Crossing the river while feeling the rocks:" Incremental land reform and its impact on rural welfare in China.* John W. Bruce and Zongmin Li, 2009.

925. *Rich food for poor people: Genetically improved tilapia in the Philippines*. Sivan Yosef, 2009.

924 *.Rural and urban linkages: Operation Flood's role in India's dairy development.* Kenda Cunningham, 2009.

923. *The global effort to eradicate rinderpest*. Peter Roeder and Karl Rich, 2009.

922. *The mungbean transformation: Diversifying crops, defeating malnutrition.* Subramanyan Shanmugasundaram, J. D. H. Keatinge, and Jacqueline d'Arros Hughes, 2009.

921. *Private sector responses to public investments and policy reforms: The case of fertilizer and maize market development in Kenya.* Joshua Ariga and T. S. Jayne, 2009.

920. *Institutional reform in the Burkinabè cotton sector and its impacts on incomes and food security: 1996–2006.* Jonathan Kaminski, Derek Headey, and Tanguy Bernard, 2009.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

www.ifpri.org

IFPRI HEADQUARTERS

2033 K Street, NW
Washington, DC 20006-1002 USA
Tel.: +1-202-862-5600
Fax: +1-202-467-4439
Email: ifpri@cgiar.org

IFPRI ADDIS ABABA

P. O. Box 5689
Addis Ababa, Ethiopia
Tel.: +251 11 6463215
Fax: +251 11 6462927
Email: ifpri-addisababa@cgiar.org

IFPRI NEW DELHI

CG Block, NASC Complex, PUSA
New Delhi 110-012 India
Tel.: 91 11 2584-6565
Fax: 91 11 2584-8008 / 2584-6572
Email: ifpri-newdelhi@cgiar.org